

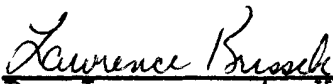
Senior Thesis

SOFT-SEDIMENT DEFORMATION STRUCTURES  
AND PALEOSLOPE INFERENCE:  
BEREA SANDSTONE (MISSISSIPPIAN)  
IN SOUTH-CENTRAL OHIO

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TABLE OF CONTENTS

ACKNOWLEDGEMENTS. . . . .	i
LIST OF TABLE AND FIGURES. . . . .	iii
ABSTRACT. . . . .	iv
INTRODUCTION	
Stratigraphy. . . . .	1
Previous Studies. . . . .	3
Objectives. . . . .	8
OUTCROP DESCRIPTION. . . . .	10
PALEOSLOPE INFERENCE FROM	
SOFT-SEDIMENT DEFORMATION STRUCTURES. . . . .	16
Methods . . . . .	17
Data and Results . . . . .	20
Discussion. . . . .	20
CONCLUSION. . . . .	27
REFERENCES CITED. . . . .	28
APPENDIX. . . . .	30

LIST OF TABLE AND FIGURES

<u>Table</u>	<u>Page</u>
1. Outcrop data collected, including total thickness of Berea, thickness of disturbed beds, thickness of undisturbed beds, and ratio of thickness of disturbed beds to thickness of undisturbed beds. . . .	21
 <u>Figure</u>	 <u>Page</u>
1. Stratigraphic column for Mississippian rocks in central and southern Ohio. . . . (after Coogan et al., 1981)	2
2. Ripple mark orientation in the Berea Sandstone as measured by Hyde (1911) . . .	4
3. Paleogeographic map of beginning of late Bedford time. . . . . (after Pepper et al., 1954)	6
4. Paleogeographic map of middle Berea time. . . . . (after Pepper et al., 1954)	7
5. Location map for Massieville section . . .	11
6. Generalized section of Massieville section (after Coogan et al., 1981). . .	12
7. Symbols for lithologies and sedimentary structures shown in stratigraphic sections. . . . .	14
8. Massieville stratigraphic section. . .	15
9. Research area; A-A', profile line for Figure 10. . . . .	19
10. Graph of the ratio of the thickness of disturbed beds to the thickness of undisturbed beds as a function of the distance from north to south over the research area. . . . .	22
11. Graph of the ratio of the thickness of disturbed beds to the thickness of undisturbed beds as a function of the total thickness of the Berea at each outcrop. . . . .	23

### ABSTRACT

The Berea Sandstone is an important oil and gas reservoir in Ohio, Pennsylvania, and West Virginia. It has been the subject of many studies. The Bedford Formation is important because of its stratigraphic position, underlying the Berea Sandstone. The Bedford-Berea sequence in Ohio has been suggested to represent a delta that prograded into the Appalachian Basin. This study concentrates on an outcrop of the Bedford-Berea sequence at Massieville, Ohio in south-central Ohio. This outcrop provides a complete section of the Bedford Formation. Soft-sediment deformation structures, known as flow rolls or ball-and-pillow structures, are notable in the Berea at this locality. In this study, the ratio of the thickness of disturbed beds to the thickness of undisturbed beds is calculated at this locality, and compared to data from previous studies from central Ohio to northern Kentucky. A decreasing pattern in the abundance of flow rolls is noted from north to south, suggesting that the influence of the prograding delta lobe is decreasing from north to south. However, it is found that the utilization of this ratio to be used as a means to infer paleoslope is not possible.

## INTRODUCTION

The Berea Sandstone has long been studied because of its properties as an important oil and gas reservoir. The Bedford Formation, which underlies the Berea Sandstone, has received similar attention because of its stratigraphic position. The Bedford Formation was first described and named by J. S. Newberry (1870) from the type locality near Bedford, Ohio. Newberry (1870) also first described and named the Berea Sandstone from the type locality near Berea, Ohio

### Stratigraphy

In south-central Ohio, the Bedford Formation overlies the Ohio Shale, a fissile, carbonaceous shale, that is late Devonian in age (Figure 1). The contact between the Ohio Shale and the Bedford Formation is conformable in south-central Ohio, and is suggested to represent the contact between the Devonian and Mississippian Systems. The Bedford Formation is divided into a lower and an upper member in south-central Ohio. The lower Bedford Formation is a gray, weakly fissile shale. The upper Bedford Formation is a gray, weakly fissile shale interbedded with thin (0.5-3.0 cm) to thick (7-15 cm) rippled siltstones. The contact between the upper Bedford Formation and the Berea

SYSTEM	FORMATION	LITHOLOGY
PENN.	SHARON	
MISSISSIPPIAN	MAXVILLE	
	LOGAN	
	CUYAHOGA	
	SUNBURY	
	BEREA	
	BEDFORD	
DEV.	OHIO SHALE	

Figure 1: Stratigraphic column for Mississippian rocks in central and southern Ohio (after Coogan, et. al., 1981)

Sandstone is gradational in south-central Ohio (Carman, 1947). The Berea Sandstone is a fine-grained sandstone that exhibits horizontal bedding, low-angle cross stratification, and rippled beds. Soft-sediment deformation structures, known as flow rolls or ball-and-pillow structures, are common in the Berea Sandstone. The deformation has destroyed the original bedding. The Sunbury Shale conformably overlies the Berea Sandstone in south-central Ohio. The contact between the Berea Sandstone and the Sunbury Shale is sharp. The Sunbury Shale is a fissile, carbonaceous shale. Because of the stratigraphic position of the Bedford-Berea sequence between the Ohio Shale and the Sunbury Shale, its age is inferred to be early Mississippian.

### Previous Studies

The Bedford-Berea sequence has been studied extensively due to its economic significance. Hyde (1911) conducted one of the first studies showing the consistency of oscillation ripple orientations in the Berea Sandstone from central Ohio to northern Kentucky (Figure 2). The soft-sediment deformation structures that are commonly noted in the upper Bedford Formation and the Berea Sandstone were studied by Cooper (1943). He described these flow structures from exposures of the Berea Sandstone in central Ohio. Cooper (1943) proposed a mode of formation of these structures, which included deposition on a slope, composition of the sediments, decreased friction in the mass, weight of the sediments, and outside forces.

The first comprehensive outcrop and subsurface study of a



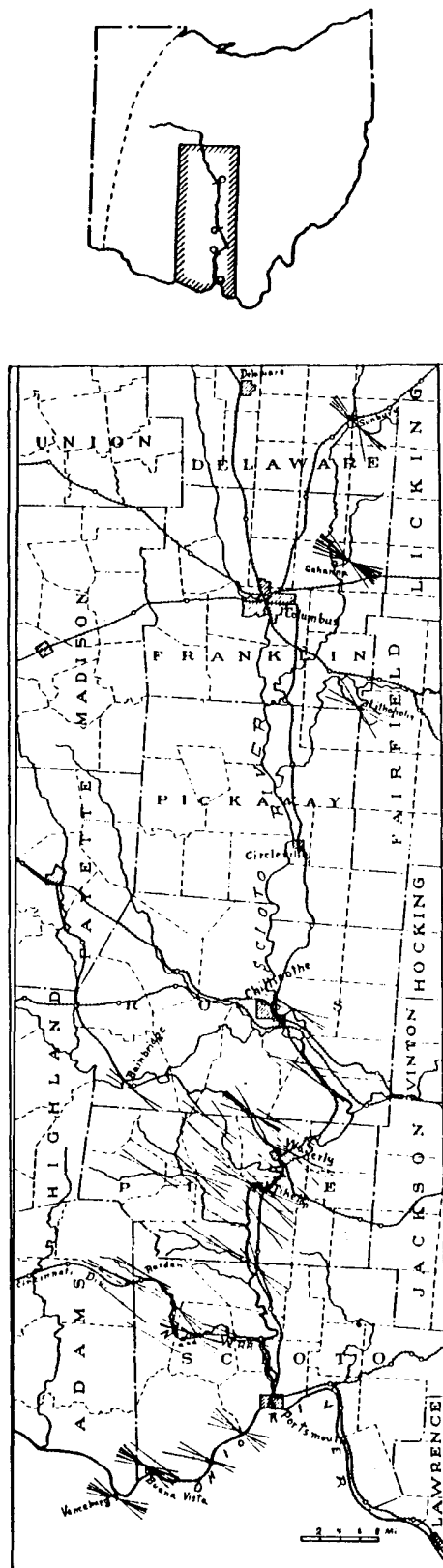


Figure 2: Ripple mark orientation in the Berea Sandstone as measured by Hyde (1911)

sandstone across an entire basin was a study of the Bedford and the Berea by Pepper and others (1954). This classic study inferred the paleogeography of Ohio during the late Devonian and the early Mississippian (Figures 3 and 4). Pepper et al. (1954) suggested that the Bedford-Berea sequence formed a delta, similar to the Mississippi Delta, which prograded into a shallow, epeiric sea. Coogan and others (1981) suggested that the Bedford-Berea sequence in central and southern Ohio is mainly composed of deltaic and shallow-marine deposits. However, they suggested that the siltstones and sandstones in southern Ohio may be turbidites. Potter et al. (1983) used outcrop and subsurface data to infer that the Berea Sandstone was deposited by deltaic processes. They suggested that the Bedford-Berea of central and southern Ohio is a shallow-marine-shelf deposit. Pashin and Ettensohn (1987) suggested that the Bedford-Berea sequence in northern Kentucky and southern Ohio represents the progradation of a storm-dominated shelf into an oxygen-deficient basin.

Coats (1988) provided an extensive study of the upper Devonian-lower Mississippian in central Ohio utilizing modern sedimentological techniques. Following Pepper et al. (1954), Coats (1988) suggests that the contact between the Ohio Shale and the Bedford Formation marks the introduction of oxygen into an anaerobic basin. Coats (1988) also interprets the Bedford Formation as a shoaling-and coarsening-upward sequence of pro-deltaic sediments. The numerous siltstone stringers that are common in the upper Bedford Formation represent the distal ends of storm-generated turbidites (Coats, 1988). The appearance of

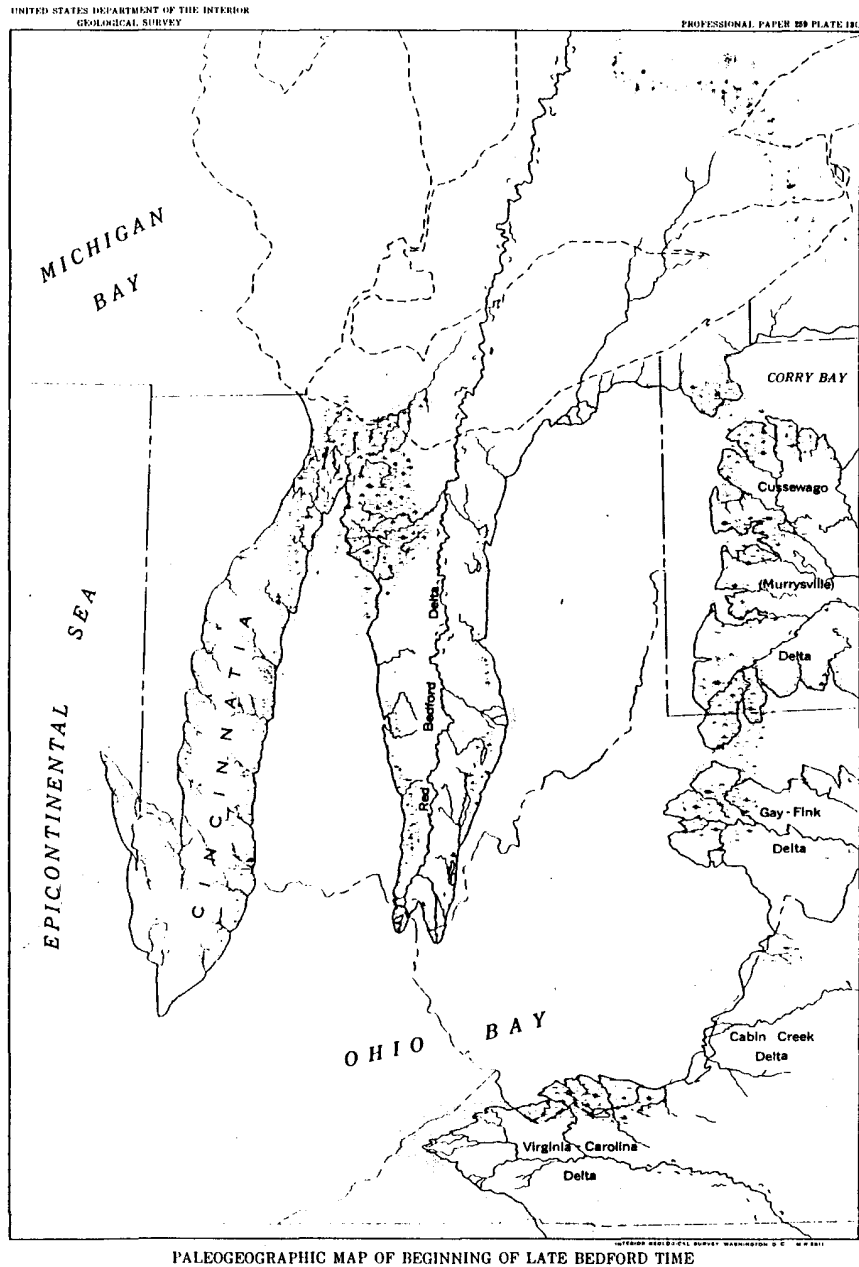


Figure 3: Paleographic map (after Pepper, et al., 1954)

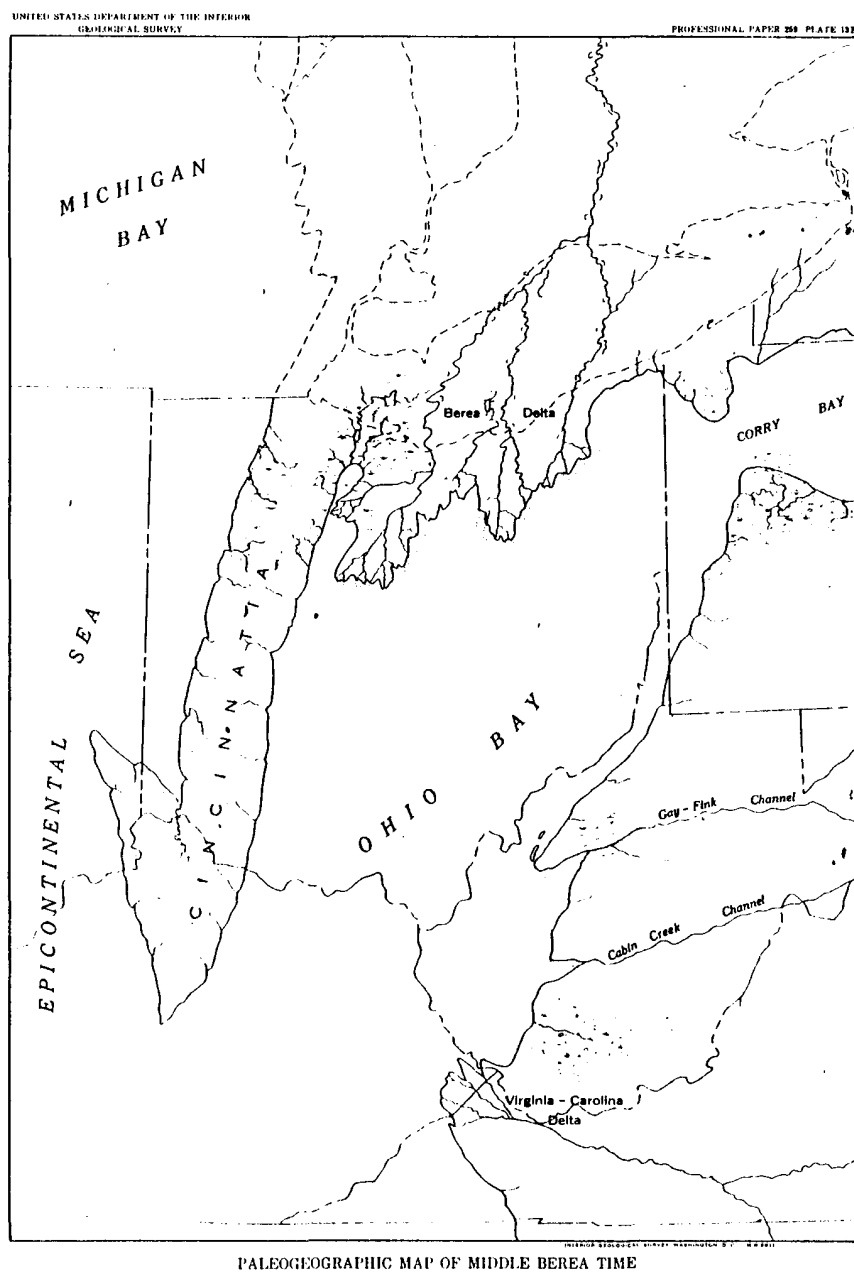


Figure 4: Paleogeographic map (after Pepper, et al., 1954)

these siltstone stringers records the approach of the Berea Sandstone deltaic complex. The Berea Sandstone is inferred to represent storm-dominated, delta front sediments with continued shoaling- and coarsening-upward (Coats, 1988).

### Objectives

The first part of this study is a description of an outcrop of the upper Devonian and lower Mississippian rocks south of Chillicothe, Ohio along State Route 23 and Three Locks Road. The outcrop provides a complete section of the Bedford Formation. The contacts between the Ohio Shale and the lower Bedford Formation, and the upper Bedford Formation and the Berea Sandstone are noted at this outcrop. Coogan et al. (1981) and Potter et al. (1983) give brief descriptions of this outcrop, but it is apparent that the outcrop deserves further study. This study concentrates on the exposures of the upper Bedford Formation and the Berea Sandstone at Massieville, Ohio.

The second part of this study compares the data collected at this locality with data collected by previous workers from other outcrops in central Ohio, southern Ohio, and northern Kentucky. As noted previously, soft-sediment deformation structures, known as flow rolls, are common in the Berea Sandstone. This deformation has destroyed some sections of the original bedding in the Berea Sandstone. Other sections remain intact, showing the thin bedding characteristic of the Berea. From the outcrops studied by Potter et al. (1983), Coats (1988),

and the present study, a ratio of the thickness of disturbed beds to the thickness of undisturbed beds for each outcrop will be determined. This will enable the distribution of flow rolls to be studied from central Ohio to northern Kentucky. By examining the distribution of flow roll abundance in the Berea Sandstone, it may be possible to use these structures to determine the position of increased bottom slopes in the ancient deltaic complex that prograded into the Appalachian Basin from the north.

### OUTCROP DESCRIPTION

The outcrop in this study is located south of Chillicothe, Ohio, at the intersection of Three Locks Road and State Route 23 (Figure 5). The outcrop can be seen from State Route 23. Turn off of 23 onto State Route 104 and Three Locks Road. Turn left at the stop sign, and then turn left onto Renick Road (dead-end road). Park 0.1 mi. from the intersection on the right. The outcrop is located on the property of Mr. Ray DePugh.

A total of 23.3 m of section was measured up a small drainage feature on the face of the outcrop (Figure 6). The Ohio Shale, a black, fissile shale, is exposed at the base of the outcrop. The contact between the Ohio Shale and the lower Bedford Formation lies at the floor of the quarry. The lower Bedford Formation is a gray, weakly fissile, slope-forming shale. A yellow band is noted at the top of the lower Bedford Formation. Coogan et al. (1981) attribute this band to differing permeabilities in the upper and lower members of the Bedford Formation. The base of the upper Bedford Formation is taken as the top of this yellow band. The measured section begins at the base of the upper Bedford Formation.

The 23.3 m of measured section include 18.5 m of the upper Bedford Formation and 4.8 m of the Berea Sandstone (Figure 8).

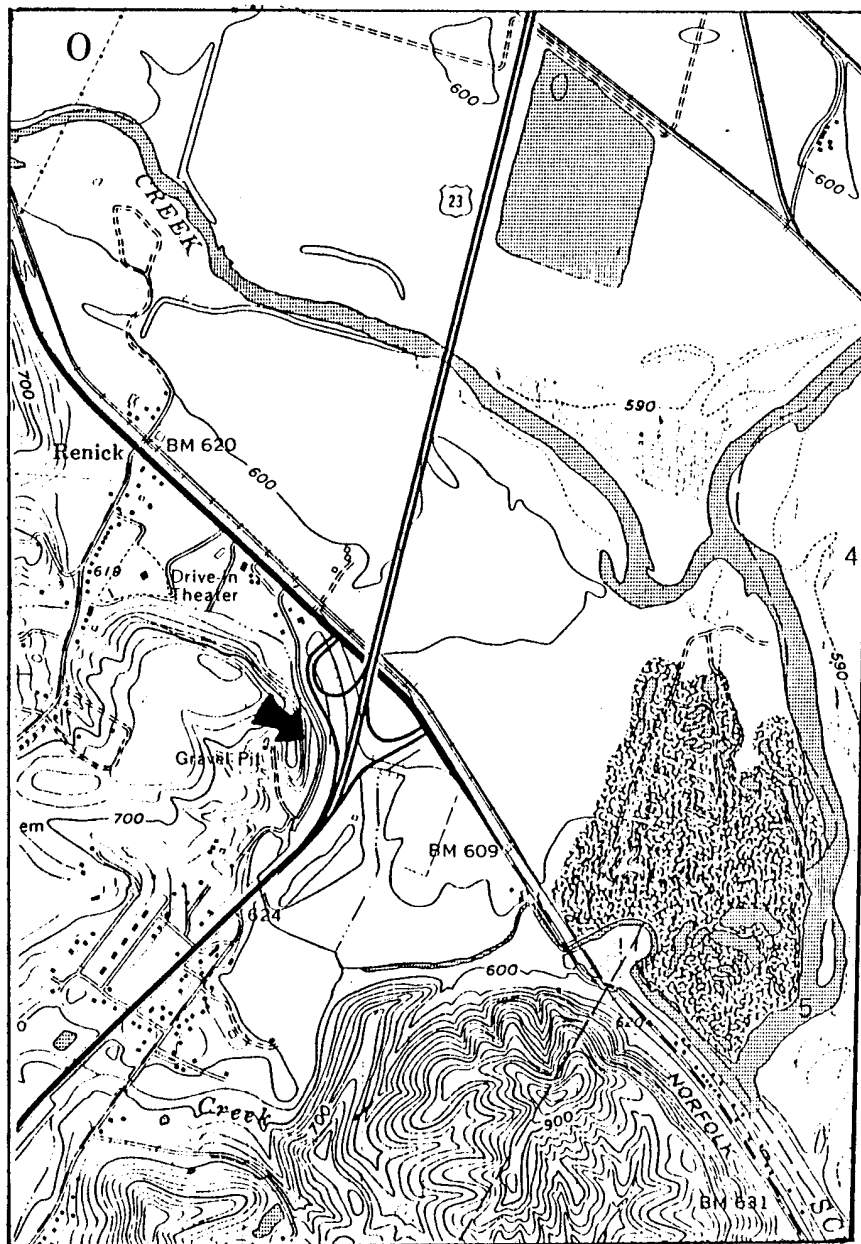


Figure 5: Location map (Chillicothe East, 7- $\frac{1}{2}$  Minute Quadrangle)

Contour Interval 20 feet



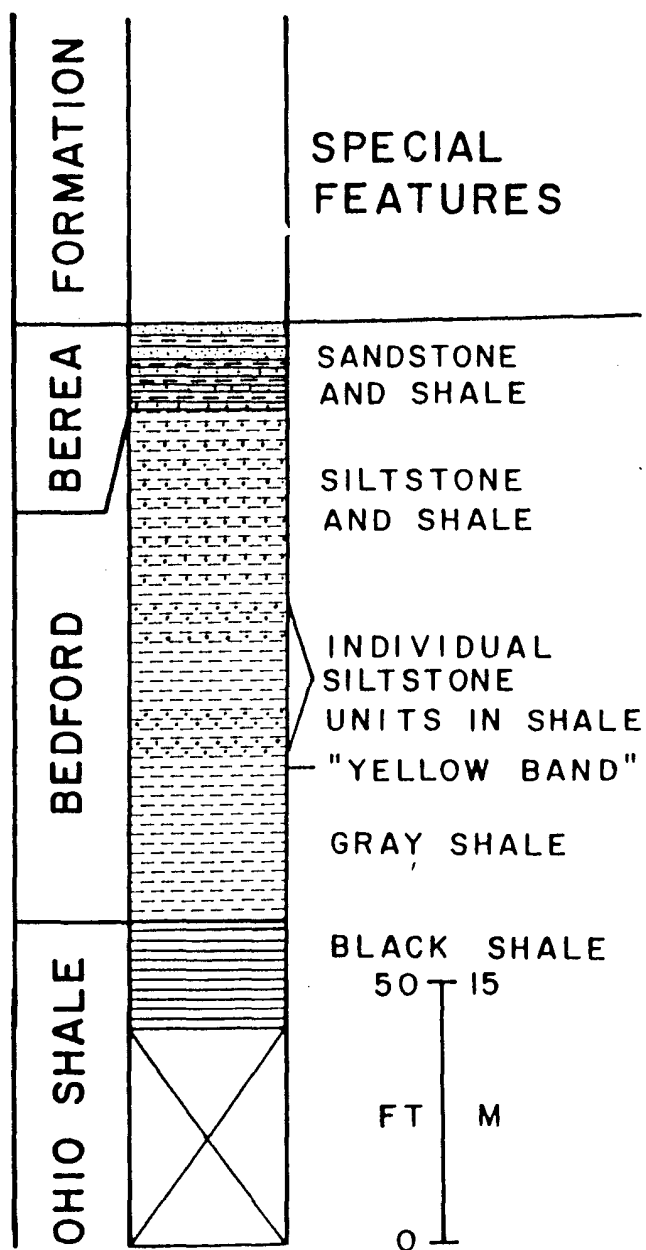


Figure 6: Generalized section of Massieville section (after Coogan, et. al., 1981)

The upper Bedford Formation is a gray, weakly fissile shale, thinly interbedded with rippled siltstones (0.5-3 cm thick). Moving upsection, the amount of thin rippled siltstones increases. Near the contact between the upper Bedford Formation and the Berea Sandstone the shale is virtually gone, and wavy to lenticular bedding becomes much more common. The slightly asymmetric to symmetric ripples are stacked upon each other, suggesting that the rate of sediment input is increasing. Laterally persistent siltstone beds up to 10 cm thick are found throughout the upper Bedford Formation. These include massive to horizontally laminated beds with flat tops, beds with horizontal laminations grading upward into cross laminae, and beds with slightly asymmetric to symmetric ripples. The contact between the Bedford and the Berea is gradational, and taken as the first laterally persistent fine-grained sandstone bed. The lower 1.3 m of the Berea show plane bedding, low-angle, low-amplitude cross bedding, and symmetric ripples. The beds are thin (1-3 cm). An interval of thin rippled siltstone interbedded with shale is also present within the Berea. The upper 3.5 m of Berea exhibit soft-sediment deformation structures, known as flow rolls. The original bedding has been destroyed by the deformation, so that the sandstone is now in large blocks or balls. Thin shale layers have been contorted around the bases of these large balls. Shale has also been squeezed between the blocks.

## EXPLANATION

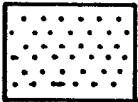
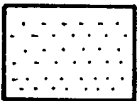
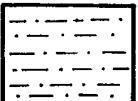

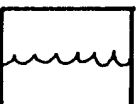
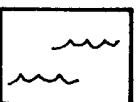
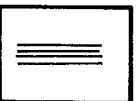
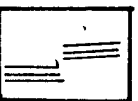
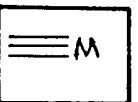
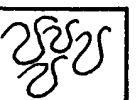
	Fine-grained sandstone
	Siltstone
	Shale thinly interbedded with siltstone
	Shale
	Symmetrical to asymmetrical ripples
	Discontinuous ripples--wavy to lenticular bedding
	Horizontal bedding
	Planar to low-angle stratification
	Massive beds with planar tops
	Flow rolls or ball-and-pillow structures

Figure 7: Symbols for lithologies and sedimentary structures shown in stratigraphic section

# MASSIEVILLE SECTION

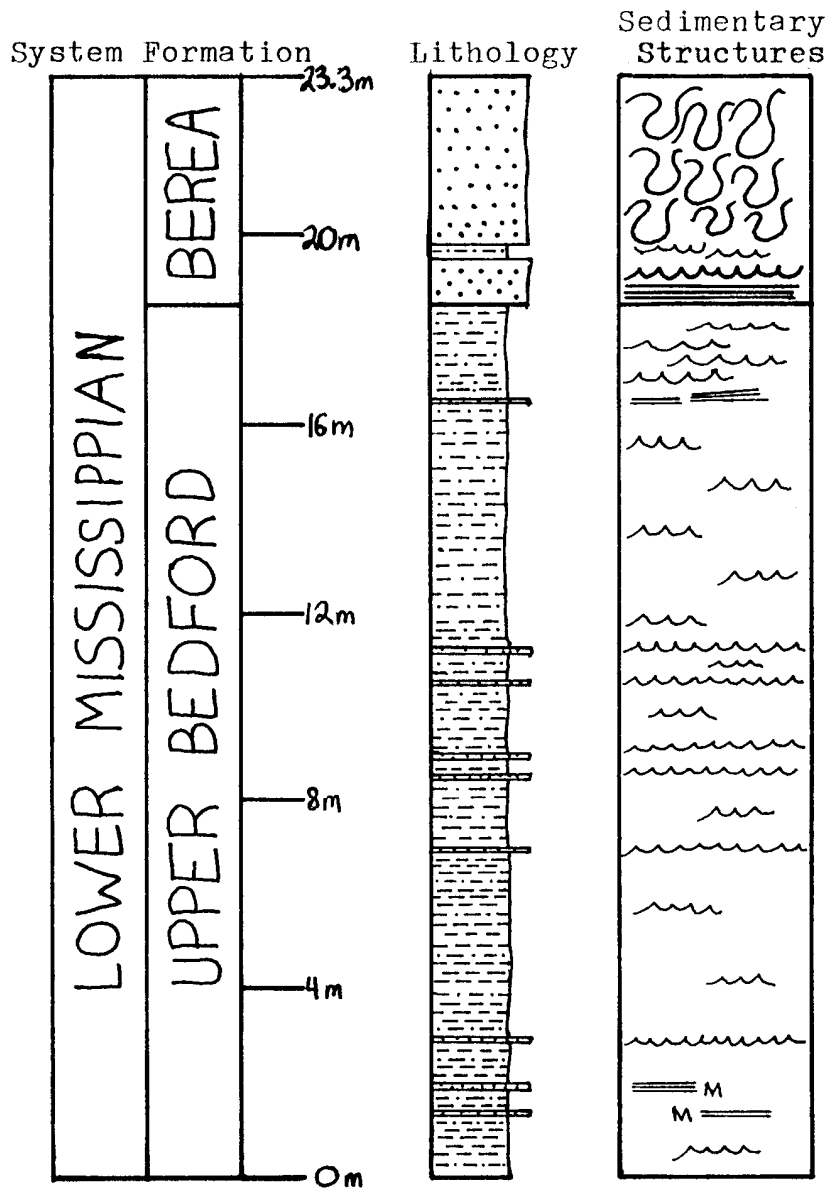


Figure 8: Massieville section

PALEOSLOPE INFERENCE FROM  
SOFT-SEDIMENT DEFORMATION STRUCTURES

Soft-sediment deformation structures are commonly noted in exposures of the Berea Sandstone in south-central Ohio. The soft-sediment deformation structures are described as storm rollers (Chadwick, 1931), flow structures (Cooper, 1943), flow rolls (Pepper et al., 1954), and ball-and-pillow structures (Allen, 1982). Following Pepper et al. (1954) and Coats (1988), the term flow rolls will be used to describe these soft-sediment deformation structures.

Cooper (1943) described flow rolls at Sunbury and Rocky Fork. Cooper (1943) proposed the following as possible origins for the flow rolls: (1) deposition on a slope, (2) presence of mud mixed with sand, (3) decreased friction in the mass, (4) weight of the sediments, and (5) outside impulses. Cooper (1943) provides an explanation of each of these possible causes, and concluded that "surface slope is considered the fundamental cause of the Bedford and Berea flows, although it cannot be proved that any particular flow was caused thereby." Outside impulses, such as earthquakes and storm waves, are not considered to be important in the origin of flow rolls in the Berea (Cooper, 1943). Pepper et al. (1954) attributed the flow rolls in the

Berea Sandstone to the horizontal flowage of sediments in response to unequal loading of the more mobile substratum of mud. It is noted that a slope of a few degrees would contribute to the formation of flow rolls, but should not be considered the driving force (Pepper et al., 1954).

Coats (1988) suggested that the abundance of soft-sediment deformation structures in the Berea is evidence for rapid deposition characteristic of storm-generated density currents. Duke (1985) included the Berea in a group of sediments most likely to have formed as a result of intense tropical storms. It is suggested that outside forces, such as storm waves, may have formed the flow rolls in the Berea. Minor tremors and earthquakes have also been suggested as outside forces capable of forming soft-sediment deformation structures (Allen, 1986). Pashin and Ettensohn (1987) suggested that the prevalence of flow rolls, load casts, and other soft-sediment deformation structures in the Bedford-Berea sequence may indicate penecontemporaneous seismicity related to a fault along the Kentucky-Ohio border. Cyclic stresses, such as storm waves and earthquakes, are probably the most effective mechanism to liquefy sediments and produce a density inversion (Allen, 1985).

### Methods

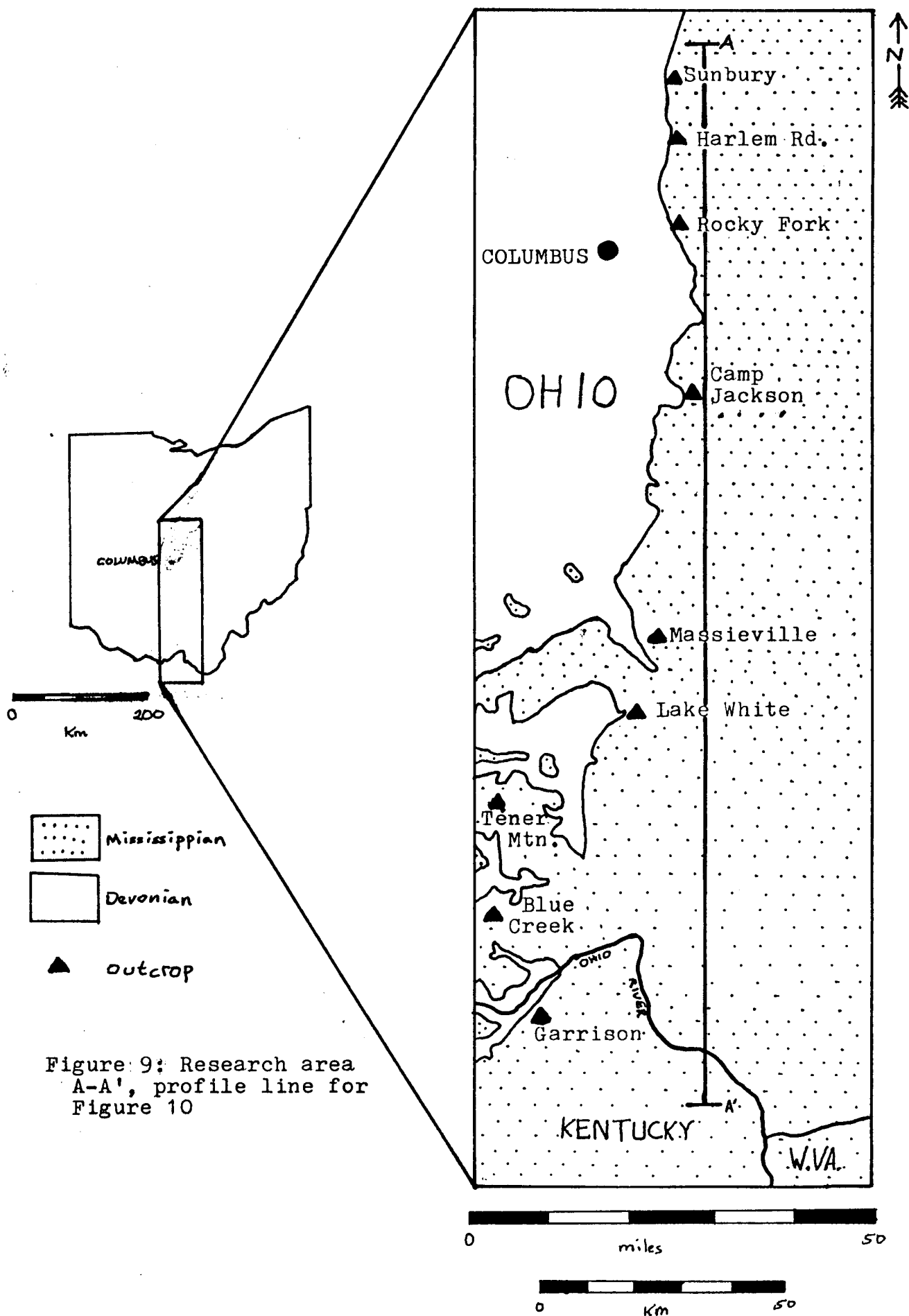
The objective of this part of the study is to examine the distribution of soft-sediment deformation structures from central Ohio to northern Kentucky, and to determine if these structures can be used to infer the position of increased bottom slopes in

the ancient deltaic complex that prograded into the Appalachian Basin from the north.

These outcrops were chosen for this study because soft-sediment deformation structures are common in the Bedford and the Berea. The data for each outcrop were obtained from stratigraphic sections and outcrop descriptions provided in Potter et al. (1983), Coats (1988), and this study (Figure 9). For each outcrop, the total thickness of Berea, the thickness of disturbed beds, and the thickness of undisturbed beds were determined (Table 1). The total thickness of Berea is the true Berea thickness if a complete section of Berea is exposed. The total Berea thickness at an outcrop is an estimate of the total Berea thickness if the section is not complete. Disturbed beds are defined as those that exhibit soft-sediment deformation structures, known as flow rolls. The original bedding is destroyed to yield large sand balls (up to 3 m) with thin contorted shales wrapped around the base and squeezed between the balls. Undisturbed intervals can exhibit thin rippled beds, low-angle, low-amplitude cross stratification, and planar bedding.

The ratio of the thickness of disturbed beds to the thickness of undisturbed beds was then calculated. In order to determine if there is a correlation between the amount of soft-sediment deformation and position relative to the ancient delta, the values are plotted on two graphs. The first graph is the ratio as a function of position from north to south over the research area (Figure 10). The second graph is the ratio as a function of the total thickness of Berea at each outcrop (Figure 11).

## RESEARCH AREA





## Data and Results

From Table 1, it is noted that the ratio of the thickness of disturbed beds to the thickness of undisturbed beds generally decreases from central Ohio (Sunbury) to northern Kentucky (Garrison). However, the amount of soft-sediment deformation exposed in the Massieville section is higher than that in the surrounding outcrops. Figure 10, which is a plot of the ratio of the thickness of disturbed beds to the thickness of undisturbed beds as a function of the distance from north to south in the research area, exhibits this pattern of generally decreasing ratios. The large value determined for the Massieville section is noticeable on this graph.

Figure 11 is a plot of the ratio of the thickness of disturbed beds to the thickness of undisturbed beds as a function of the total thickness of the Berea at each outcrop. The total thickness at each outcrop represents either the true total thickness or a minimum estimate of the total thickness. High amounts of soft-sediment deformation are noted at exposures of incomplete sections of Berea. Where a section contains the complete Berea interval, the variation in the ratio is slight, and the ratio values are low.

## Discussion

The abundance of soft-sediment deformation structures decreases from north to south in the research area. However, there is a great increase in the amount of soft-sediment

# DATA TABLE

OUTCROP	TOTAL THICKNESS BEREA (m)	MAXIMUM OR MINIMUM THICKNESS	THICKNESS DISTURBED BEDS (m)	THICKNESS UN- DISTURBED BEDS (m)	<u>DIST.</u> UNDIST.
SUNBURY <sub>1</sub>	5.5	MIN	3.3	2.2	1.50
HARLEM ROAD <sub>1</sub>	9.8	MIN	2.8	7.0	0.40
ROCKY FORK <sub>1</sub>	10.2	MAX	1.3	8.9	0.15
CAMP JACKSON <sub>1</sub>	1.8	MAX	0.0	1.8	0.00
MASSIEVILLE <sub>2</sub>	4.8	MIN	3.5	1.3	2.70
LAKE WHITE <sub>3</sub>	11.12	MIN	0.88	10.24	0.08
TENER MOUNTAIN <sub>3</sub>	8.89	MAX	0.0	8.89	0.00
BLUE CREEK <sub>3</sub>	18.4	MAX	1.49	16.19	0.09
GARRISON <sub>3</sub>	18.0	MIN	2.1	15.9	0.13

Table 1: Outcrop data and calculated ratio of thickness of disturbed beds to thickness of undisturbed beds

<sub>1</sub>Coats (1988)

<sub>2</sub>Present study

<sub>3</sub>Potter et. al. (1983)

Figure 10: Ratio of thickness of disturbed beds to thickness of undisturbed beds as a function of the distance from north to south over the research area

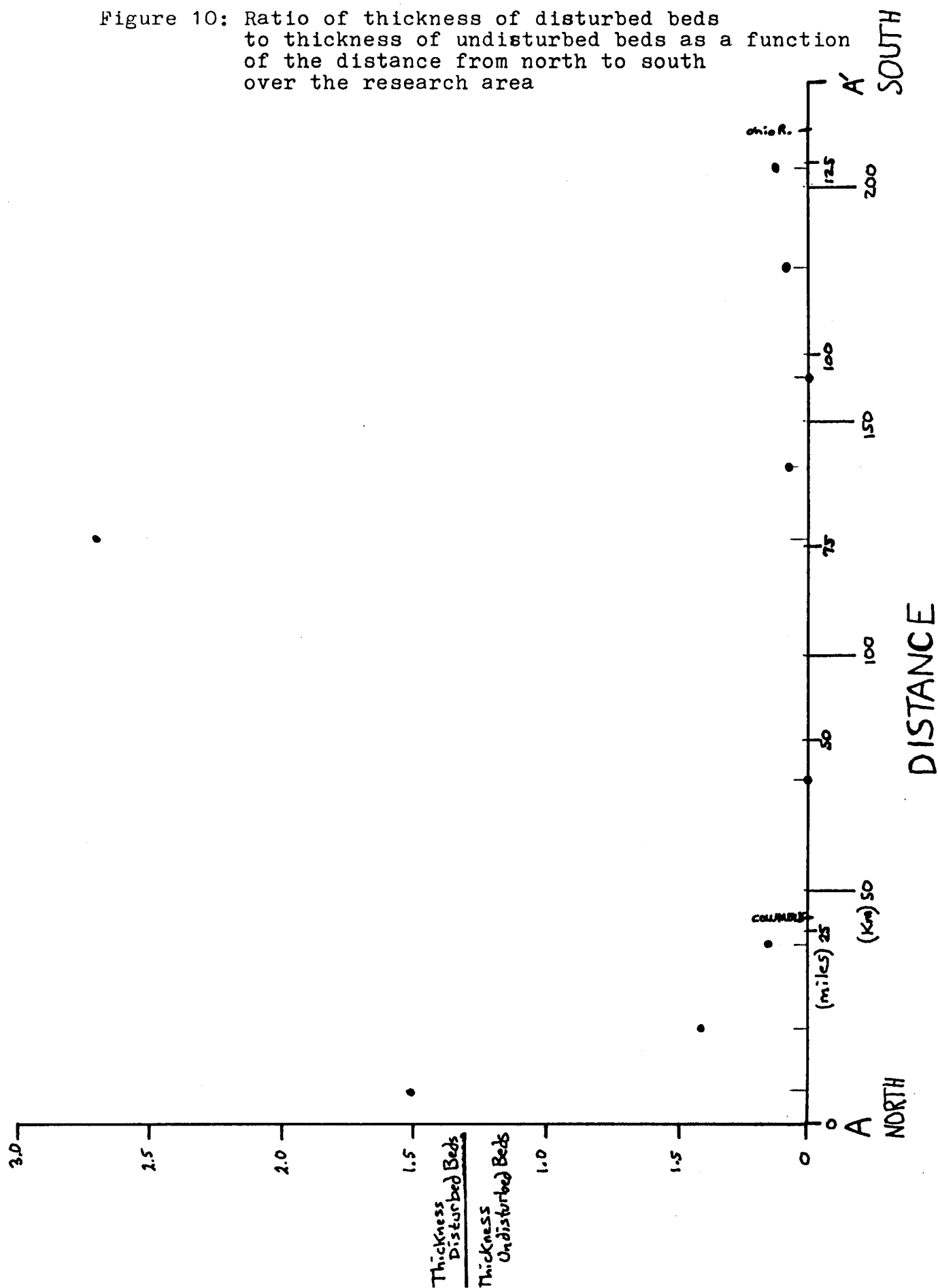
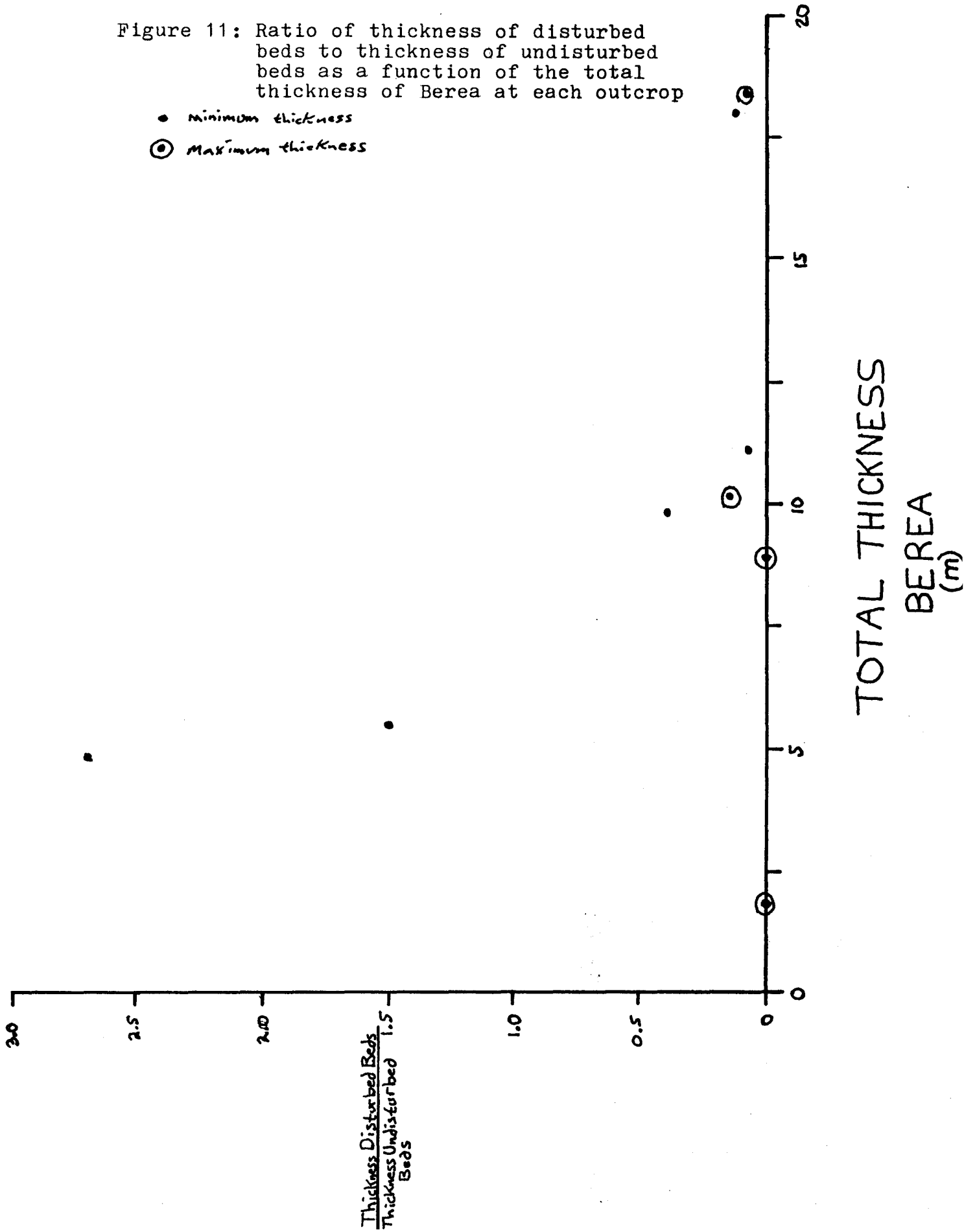


Figure 11: Ratio of thickness of disturbed beds to thickness of undisturbed beds as a function of the total thickness of Berea at each outcrop

- minimum thickness
- ⊙ maximum thickness



deformation in the Massieville section. This may be attributed to an undisturbed interval of Berea missing from this section. From Sunbury to Camp Jackson, the amount of soft-sediment deformation decreases. The Berea thins drastically at Camp Jackson. Coats (1988) attributed this thinning to the decreased influx of sediments from the deltaic lobe, and a north-east paleo-storm track across the front of the delta. The pattern of decreasing soft-sediment deformation abundance is inferred to represent a decrease in the influence of the ancient deltaic lobe from Sunbury to Camp Jackson.

The high ratio of disturbed beds to undisturbed beds at the Massieville section is probably due to the low total thickness of Berea exposed at this locality. Carman (1947) measured the Berea from a test-core taken near the Massieville section, and found the Berea thickness to be 7.8 m. If the rest of the Berea was undisturbed, the disturbed to undisturbed ratio would be 0.81. The incomplete section of Berea exposed at the Massieville outcrop is an explanation for such a high ratio of disturbed beds to undisturbed beds.

The sections in southern Ohio exhibit a low ratio of beds with soft-sediment deformation structures. This is inferred to represent a continued decrease in the influence of the deltaic lobe that prograded from the north to the south. It has been suggested by previous workers that additional deltaic lobes may have prograded into the Appalachian Basin from the east and south-east (Pepper et al., 1954, and Pashin and Ettensohn, 1987). The sections in southern Ohio

may be exhibiting the distal effects of the deltaic lobes prograding from the east and the south-east. The ratio of disturbed beds to undisturbed beds increases slightly at Blue Creek and Garrison. At Garrison, this could reflect the incompleteness of the section. The Garrison and Blue Creek sections ~~are~~ are inferred to represent the distal effects of the delta prograding from the north, and an additional lobe prograding from the east and south-east (Pashin and Ettensohn, 1987).

Inaccurate stratigraphic sections and outcrop descriptions produce some error in this study. In order to clearly test if the amount of soft-sediment deformation can be used to infer position on the ancient delta slope, the ratios should ideally be plotted on an isopach map of the Berea Sandstone. An isopach map of the Berea Sandstone was not available for this study area, however. Although a pattern of decreasing soft-sediment deformation abundance is noted from north to south, the problems associated with this study do not allow the utilization of this ratio to be used as a means to infer paleoslope. At best, it provides evidence of the influence of the deltaic lobe in relation to the outcrop. The decrease in the abundance of flow rolls also suggests that rate of sedimentation may be decreasing.

Pashin and Ettensohn (1987) noted that the prevalence of soft-sediment deformation structures in the Berea supports the interpretation of a fault along the Kentucky-Ohio border. In the present study, it is found that larger amounts of soft-

sediment deformation occur 75 to 100 km north of the proposed fault. The amount of soft-sediment deformation in the region of this proposed fault is low compared to the northern localities. It is suggested that the force responsible for these flows is an increase in the rate of sedimentation due to storm action, and not to seismic activity.

## CONCLUSION

The Massieville section exhibits a coarsening-upward sequence. Following Coats (1988), it has been suggested that the Bedford represents shoaling- and coarsening upward prodeltaic sediments, and the Berea represents shoaling- and coarsening-upward, storm-dominated delta front sediments in central Ohio. The Massieville section exhibits many of the same structures and lithologies noted at the central Ohio outcrops of the Bedford-Berea sequence by Coats (1988). The Massieville section is inferred to represent this interpretation of the Bedford-Berea sequence in south-central Ohio.

Soft-sediment deformation structures, known as flow rolls, are noted in the Berea at the Massieville section. A decreasing abundance of flow rolls is noted from north to south over the research area. This is inferred to represent a decreasing influence of the ancient deltaic lobe prograding into the Appalachian Basin from the north, and a decrease in the rate of sedimentation. The outcrops in southern Ohio and northern Kentucky exhibit a low ratio of flow rolls. This is inferred to represent the distal effects of the deltaic lobe prograding from the north, and an additional deltaic lobe prograding from the east and south-east. Although a pattern of decreasing abundance of flow rolls from north to south was noted in the data, the inability to plot these data on an isopach map of the Berea Sandstone does not allow the utilization of these structures to be used to infer paleoslope. The structures do provide evidence for position relative to the deltaic lobe and rate of sedimentation.



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## APPENDIX

Description of the stratigraphic section measured in this study. Unit intervals measured in meters.

### Massieville Section

The outcrop is located south of Chillicothe, Ohio at Three Locks Road and State Route 23 (Figure 5). Turn off 23 onto State Route 104 and Business Route 23. Turn left at the stop sign, and then turn left onto Renick Road (dead-end road). Park on the right 0.1 mi. from the intersection. Access to the outcrop can be secured by contacting Mr. Ray DePugh. The measured section begins at the base of the upper Bedford Formation, which is taken as the top of the yellow band (Figure 6). Figure 8 is the section measured in this study.

Bottom of Interval	Top of Interval	Description
0	1.4	<b>Upper Bedford Shale</b> Gray, weakly fissile shale thinly interbedded with rippled siltstones (1-2 cm thick)
1.4	1.5	Laterally persistent, buff to gray siltstone bed, massive to horizontally laminated, top is planar
1.5	1.9	Gray, weakly fissile shale interbedded with thin rippled siltstones (1-2 cm thick)
1.9	2.0	Laterally persistent, buff to gray siltstone bed, massive to horizontally laminated, top is planar

Bottom of Interval	Top of Interval	Description
2.0	3.0	Gray, weakly fissile shale interbedded with thin rippled siltstones (0.5-2 cm thick)
3.0	3.1	Laterally persistent, buff to gray siltstone bed, containing slightly asymmetric to symmetric ripples
3.1	7.0	Gray, weakly fissile shales interbedded with thin, rippled siltstones (1-3 cm thick)
7.0	7.1	Laterally persistent, buff to gray siltstone, slightly asymmetric to symmetric ripples
7.1	8.4	Gray, weakly fissile shales interbedded with thin rippled siltstone (0.5-3 cm thick) more frequently
8.4	8.5	Laterally persistent, buff to gray siltstone, slightly asymmetric to symmetric ripples
8.5	8.9	Gray, weakly fissile shale thinly interbedded with rippled siltstone (1-3 cm thick)
8.9	9.0	Laterally persistent, buff to gray siltstone, slightly asymmetric to symmetric ripples
9.0	10.4	Thin, stacked, rippled siltstones (1-4 cm thick) interbedded with gray, weakly fissile shale, lenticular to wavy bedding
10.4	10.5	Laterally persistent, buff to gray siltstone with thin rippled laminae
10.5	11.0	Gray, thin rippled siltstone (1-2 cm thick) interbedded with shale, lenticular to wavy bedding

Bottom of Interval	Top of Interval	Description
11.0	11.1	Laterally persistent, buff to gray, rippled siltstone
11.1	16.4	Gray, thin, rippled siltstone (0.5-3 cm thick) interbedded with gray shale, lenticular to wavy bedding, stacked rippled siltstones common
16.4	16.5	Buff to gray, laterally persistent, siltstone, horizontally laminated at the base, cross laminae at top
16.5	18.5	Gray, thin, rippled siltstones (0.5-2 cm thick) interbedded with gray shale, lenticular to wavy bedding, shale much less common
18.5	19.5	<b>Berea Sandstone</b> Buff, fine-grained sandstone, horizontal bedding, low-angle, low-amplitude cross bedding, symmetrical ripples, beds 1-3 cm thick
19.5	19.8	Gray, thin, rippled siltstones (1-2 cm thick) interbedded with shale
19.8	23.3	Bedding destroyed by soft-sediment deformation, massive balls of fine-grained sandstone, thinner shale beds contorted around base of balls or squeezed between them, flow rolls or ball-and-pillow structures
23.3	---	Cover